

CLAIMS

1. A device comprising a mechanical structure micromachined in or on a substrate, said mechanical structure comprising a compliant support structure, and a member supported by said compliant support structure, wherein said compliant support structure changes size or shape during movement of said member.

2. The device as recited in claim 1, wherein said member comprises a membrane and a first electrode supported by said membrane, and further comprising a second electrode disposed at a distance from said first electrode to form a capacitor with a cavity disposed therebetween, wherein said compliant support structure changes size or shape during compression/expansion of said membrane.

3. The device as recited in claim 2, further comprising a pedestal, said second electrode being supported by said pedestal.

5 4. The device as recited in claim 2, wherein said compliant support structure comprises a first wall, a ring-like structure having an inner peripheral portion and an outer peripheral portion, one of said inner and outer peripheral portions being built on said first wall, and a second wall built on the other of said inner and outer peripheral portions and connected to said membrane.

10 5. The device as recited in claim 4, further comprising a third electrode formed on a surface of said ring-like structure.

6. The device as recited in claim 5, further comprising a fourth electrode formed on a surface of said membrane and forming a capacitor with said third electrode.

15 7. The device as recited in claim 5, further comprising a fourth electrode formed on a surface of said substrate and forming a capacitor with said third electrode.

8. The device as recited in claim 2, wherein said compliant support structure in cross section resembles a cantilevered beam

9. The device as recited in claim 2, wherein said compliant support structure comprises:

5 a first wall;

 a first ring-like structure having an inner peripheral portion and an outer peripheral portion, one of said inner and outer peripheral portions of said first ring-like structure being built on said first wall;

10 a second wall built on the other of said inner and outer peripheral portions of said first ring-like structure;

 a second ring-like structure overlying said first ring-like structure and having an inner peripheral portion and an outer peripheral portion, one of said inner and outer peripheral portions of said second ring-like structure being built on said second wall; and

15 a third wall built on the other of said inner and outer peripheral portions of said second ring-like structure and connected to said membrane.

10. The device as recited in claim 9, further comprising a third electrode formed on a surface of one of said first and second ring-like structures.

20 11. The device as recited in claim 2, wherein said compliant support structure in cross section resembles a double cantilevered beam.

12. The device as recited in claim 2, wherein the compliance of said compliant support structure and the stiffness of said membrane are selected so that said membrane vibrates in a piston-like manner.

25 13. A cMUT cell array comprising a compliant support structure, a first membrane supported over a first cavity by said compliant support structure,

a first electrode supported by said first membrane, a second electrode that forms a capacitor with said first electrode, said first cavity being disposed between said first and second electrodes, a second membrane supported over a second cavity by said compliant support structure, a third electrode supported
5 by said second membrane and electrically connected to said first electrode, and a fourth electrode electrically connected to said second electrode and arranged to form a capacitor with said third electrode, said second cavity being disposed between said third and fourth electrodes, and a portion of said compliant support structure being disposed between said first and second cavities.

10 14. The cMUT cell array as recited in claim 13, further comprising first and second pedestals, said second electrode being supported by said first pedestal and said fourth electrode being supported by said second pedestal.

15 15. The cMUT cell array as recited in claim 13, wherein said compliant support structure in cross section resembles a cantilevered beam.

15 16. The cMUT cell array as recited in claim 15, further comprising a fifth electrode formed on a surface of said compliant support structure, said fifth electrode being hard-wired to at least one of said first and third electrodes.

20 17. The cMUT cell array as recited in claim 15, further comprising a fifth electrode formed on a surface of said compliant support structure, said fifth electrode being hard-wired to at least one of said second and fourth electrodes.

25 18. The cMUT cell array as recited in claim 13, wherein said compliant support structure in cross section resembles a double cantilevered beam.

25 19. The cMUT cell array as recited in claim 18, further comprising a fifth electrode formed on a surface of said compliant support structure, said fifth electrode being hard-wired to at least one of said first and third electrodes.

20. The cMUT cell array as recited in claim 18, further comprising a fifth electrode formed on a surface of said compliant support structure, said fifth electrode being hard-wired to at least one of said second and fourth electrodes.

5 21. The cMUT cell array as recited in claim 13, wherein the compliance of said compliant support structure and the stiffness of each of said first and second membranes are selected so that each of said first and second membranes vibrates in a piston-like manner.

22. A device comprising a mechanical structure micromachined in or on a substrate, said mechanical structure comprising a plurality of compliant support structures, and a member supported by said compliant support structures, wherein said compliant support structures change size or shape during movement of said member.

23. The device as recited in claim 22, wherein said member comprises a membrane and a first electrode supported by said membrane, and further comprising a second electrode disposed at a distance from said first electrode to form a capacitor with a cavity disposed therebetween, wherein said compliant support structures change size or shape during compression/expansion of said membrane.

10 24. A method of manufacturing a support structure for supporting a membrane of a cMUT cell above a substrate, comprising the following steps:

(a) depositing a first layer of a first permanent material having a first thickness above a first region of said substrate having a first ring-like shape;

15 (b) depositing a first layer of a removable material having said first thickness above a second region of said substrate having a second ring-like shape and over a third region of said substrate having a third ring-like shape,

said first region being contiguous with said second region, and said second region being contiguous with said third region;

5 (c) depositing a first layer of a second permanent material having a second thickness above said first layers in an area overlying said first through third regions;

(d) depositing a second layer of said first permanent material having a third thickness above said first layer of said second permanent material in an area overlying said third region;

10 (e) depositing a second layer of said removable material having said third thickness above said first layer of said second permanent material in an area overlying said first and second regions;

15 (f) depositing a layer of membrane material above said second layer of said first permanent material and said second layer of removable material, said layer of membrane material overlying said first through third regions and a fourth region surrounded by said first through third regions; and

(g) removing said removable material without removing said first and second permanent materials or said membrane material, step (g) being performed after steps (a) through (f).

20 25. The method as recited in claim 24, wherein said first and second permanent materials are the same material.

26. The method as recited in claim 24, wherein said second permanent material has a compliance greater than said first permanent material.

25 27. The method as recited in claim 24, further comprising the steps of:

building a pedestal above said fourth region of said substrate;

depositing a first layer of electrically conductive material on at least a portion of a top surface of said pedestal;

depositing a third layer of removable material on said top surface of said pedestal; and

5 depositing a second layer of electrically conductive material on at least a portion of said third layer of removable material,

wherein membrane material is deposited on said second layer of electrically conductive material during step (f), and said third layer of removable material is removed during step (g) to form a cavity.

10 28. The method as recited in claim 24, further comprising the following steps performed after step (e) and before step (f):

depositing a second layer of said second permanent material having a fourth thickness above said second layer of said first permanent material and said second layer of removable material in an area overlying said first through third regions;

15 depositing a third layer of said first permanent material having a fifth thickness above said second layer of said second permanent material in an area overlying said first region;

20 depositing a third layer of said removable material having said fifth thickness above said second layer of said second permanent material in an area overlying said second and third regions,

wherein said third layer of removable material is removed during step (g).

25 29. The method as recited in claim 28, further comprising the steps of:

building a pedestal above said fourth region of said substrate;

depositing a first layer of metal on at least a portion of a top surface of said pedestal;

depositing a fourth layer of removable material on said metallized top surface of said pedestal; and

5 depositing a second layer of metal on at least a portion of said fourth layer of removable material,

wherein membrane material is deposited on said second layer of metal during step (f), and said fourth layer of removable material is removed during step (g) to form a cavity.

30. A cMUT cell comprising a substrate, a plurality of compliant support structures, a membrane supported over a cavity by said compliant support structures, a first electrode supported by said membrane, and a second electrode that forms a capacitor with said first electrode, said cavity being disposed between said first and second electrodes, wherein each of said compliant support structures change size or shape during compression/expansion of said membrane.

10 31. The cMUT cell as recited in claim 30, wherein said shape is a cantilever beam.

32. The cMUT cell as recited in claim 30, wherein said shape is an arch.

15 33. The cMUT cell as recited in claim 30, wherein said shape is a coil

34. A method of manufacturing a support structure for supporting a membrane of a cMUT cell above a substrate, comprising the following steps:

(a) depositing a first layer of a first permanent material having a first thickness above a first region of said substrate;

(b) depositing a first layer of a removable material having said first thickness above a second region of said substrate, said first region being contiguous with said second region;

5 (c) depositing a layer of a second permanent material having a second thickness above said first layers in an area overlying said first and second regions;

(d) depositing a second layer of said first permanent material having a third thickness above said first layer of said second permanent material in an area overlying a first portion of said second region;

10 (e) depositing a second layer of said removable material having said third thickness above said layer of said second permanent material in an area overlying said first region and a second portion of said second region, said first and second portions of said second region being non-overlapping;

15 (f) depositing a layer of membrane material above said second layer of said first permanent material and said second layer of removable material, said layer of membrane material overlying said first and second regions and a third region outside said first and second regions; and

20 (g) removing said removable material without removing said first and second permanent materials or said membrane material, step (g) being performed after steps (a) through (f).

35. A transducer element comprising: a membrane; a rigid perimeter wall, the perimeter of said membrane being attached to said rigid perimeter wall; and a plurality of transducer cells disposed within said rigid perimeter wall, each of said cells comprising a respective compliant support structure connected to a respective portion of said membrane.